APPENDIX 2: PROPULSION SUBSYSTEM REQUIREMENTS

1 SCOPE

This appendix provides additional requirements for the Propulsion Subsystem (PS) of the X-43C DV, beyond the requirements imposed on the PS by Appendix 1, X-43C DV Element Requirements. Requirements are also covered for a Flight Clearance Engine (FCE).

2 PROPULSION SUBSYSTEM DESCRIPTION

The Propulsion Subsystem is an integral part of the DV. Each PS is comprised of the Engine Subsystem (ES) with three (3) scramjet engine modules, Fuel Delivery Subsystem (FDS), Start Assist Subsystem (SAS), Igniter Spark Subsystem (ISS), Engine Control Unit (ECU) with communication link, and auxiliary components including associated electrical harnesses, sensors, and support brackets.

2.1 The ES is derived from the USAF HyTECH Program engine concept and is integrated with the DV to provide net propulsive thrust and Specific Impulse (Isp) to meet mission objectives. The ES consists of flight-weight, hydrocarbon-fueled/cooled, dual-mode scramjet flowpath/heat exchanger structures complete with all engine-mounted components. The major engine-mounted components include articulating inlet cowl flaps with actuators and fuel distribution valves with actuators.

2.2 The FDS meters and monitors JP-7 fuel to the ES for flowpath structure and component cooling, hydraulic actuation, and combustion. JP-7 fuel is passed through the flowpath heat exchangers to provide cooling for the flowpath structure and to condition the JP-7 for combustion prior to distribution to the various fuel injection sites via the fuel distribution valves. Conditioned JP-7 refers to fuel at the proper pressure, temperature, and composition for combustion in the dual-mode scramjet flowpath.

2.3 The SAS provides one of the necessary functions for starting the ES. The primary function of the SAS is to provide the necessary conditions for the initiation of combustion and transition to stable engine operation.

2.4 The ISS provides an electrical ignition source for sustained JP-7 combustion.

2.5 The ECU communicates with the DV Vehicle Management System (VMS) and provides control functions for the PS.

2.6 The Propulsion Flowpath begins at the DV forebody leading edge and continues on the DV lower surface to the DV trailing edge. The Propulsion Flowpath includes the complete engine flowpath internal geometry and extends laterally on the forebody to the forward axial projection of the engine sidewall leading edges and extends laterally on the aft body to the aft axial projection of the engine sidewall trailing edges. The Engine Flowpath includes all internal engine surface definition from the inlet cowl flap leading edge to the cowl flap trailing edge.

3 PROPULSION SUBSYSTEM (PS) REQUIREMENTS

3.1 General

3.1.1 The PS shall adhere to requirements of Appendix 1, X-43C DV Element Requirements and the additional requirements imposed herein.

3.1.2 The PS shall utilize engine design concepts developed under the USAF HyTECH Program. These engine design concepts include hydrocarbon-fuel combustion devices, flight-weight fuel-cooled flowpath/heat exchanger structures, fuel-cooled valves, and associated engine mounted components of the FDS and engine controls.

3.1.3 The Contractor shall be responsible for developing and implementing a PS design for the endothermic hydrocarbon-fuel cracking process required by the HyTECH engine concept.

3.1.4 The ES shall be comprised of three scramjet engine modules complete with engine-mounted components.

3.1.5 The Contractor shall adhere to Government furnished engine flowpath geometry as defined in X43C-GFI-007, DV Propulsion Flowpath OML Dimensions.

3.2 Performance

3.2.1 The PS shall be capable of ignition, engine operation, and controlled engine shutdown when commanded by the DV.

3.2.2 The PS shall provide adequate operation and performance to meet mission objectives over a 3-sigma Monte Carlo uncertainty variation of the relevant flight and DV system parameters.

3.3 Design

3.3.1 The PS shall be designed such that no single point failure may cause a hazardous release of propellant or other hazardous commodities during ground operations.

3.3.2 Shutoff mechanisms in the PS high-pressure subsystems shall be independent of all other subsystems and shall provide a physical interrupt.

3.3.3 The PS shall be designed to allow hard-wired communication connection between critical PS components and GSE/CAC to monitor operational readiness of the PS and perform functions as required to provide fail-safe operation whether or not mated to the Adapter and CAC.

3.3.4 The PS shall be designed to provide a minimum of one re-start after one of the following events providing the DV remains within the operating envelope of the PS: initial start malfunction, engine flameout, engine un-start, or commanded engine shutdown.

3.3.5 The ECU shall control the PS in response to PS parameters and commands from the VMS. The primary command functions of the ECU shall include inlet cowl flap position scheduling, engine start, and management of fuel delivery to the ES for cooling and maintaining stable combustion.

3.3.6 The ECU shall provide operability limiting functions that prevent combustor flameout, engine unstart, and physical limiting functions to prevent violation of fuel and structural temperature/pressure limits.

3.3.7 The ECU shall be designed to perform a controlled engine shutdown by adjusting the FDS and positioning the cowl door. Following a controlled engine shutdown, the ECU shall continue to control cowl flap position and FDS for cooling of ES structures and components, so long as fuel and power is present, through the Descent Phase.

3.3.8 The ECU shall detect engine unstart and combustor flameout conditions and provide a signal to the VMS indicating the condition.

3.3.9 ECU Software shall provide an engine-off state for software and control-hardware maintenance/testing.

3.3.10 The FDS shall be designed to provide conditioned JP-7 to support engine start and throughout the Engine Test Phase.

3.3.11 The PS shall incorporate the HyTECH engine design concept for the fuel distribution valves to distribute the fuel to the fuel-injection sites in the engine.

3.3.12 The PS portion of the OML (external engine cowl and sidewall surfaces) shall be maintained within the following manufacturing tolerances (unloaded):

- The maximum butt gap and surface mismatch shall not exceed 0.030 inches.
- Maximum exterior contour deviations shall not exceed 0.060 inches.
- Secondary profile contour shall not exceed 0.050 inches from peak-to-valley in a 6-inch span.
- The exterior surface roughness shall not exceed 125 micro-inches root mean square (rms) for metal surfaces and 250 micro-inches rms for the Thermal Protection System (TPS).

3.3.13 At the predicted aero-thermal loading conditions, the Propulsion Flowpath, inclusive of the engine flowpath and the engine-to-vehicle interfaces, shall be maintained to the following tolerances:

Propulsion Flowpath Surfaces:

- The maximum butt gap and surface mismatch shall not exceed 0.030 inches.
- Maximum profile exterior contour deviations shall not exceed 0.100 inches.
- Secondary profile contour shall not exceed 0.020 inches from peak-to-valley in any 6-inch span.
- There shall be no forward facing steps.
- Aft facing steps shall not exceed 0.020 inches.
- The exterior surface roughness shall not exceed 125 micro-inches root mean square (rms) for metal surfaces and 250 micro-inches rms for the Thermal Protection System (TPS).

Internal Engine Flowpath (from Drop/Boost through Engine Test Phase):

- Gaps shall be less than 0.020 in.
- Area variation in the inlet (up to inlet throat) shall be limited to +/- 1% for normal engine operation (excluding inlet unstart)
- Area variation in the isolator divergence section shall be limited to +/- 2% for normal engine operation (excluding inlet unstart)
- Area variation in the combustor shall be limited to +/- 1% for normal engine operation (excluding inlet unstart).
- Area variation from the combustor exit to the end of the fuel cooled structure shall be limited to +/-2% for normal operation.

4 FLIGHT CLEARANCE ENGINE REQUIREMENTS

4.1 The Contractor shall provide a Flight Clearance Engine (FCE) and its necessary GSE to be tested in the NASA LaRC Eight-Ft. High Temperature Tunnel (8-Ft. HTT).

4.2 The FCE shall be identical to the flight PS design, except as required to facilitate ground testing.

4.3 The FCE shall meet the requirements of Model Systems Criteria Handbook, LAPG 1710.15.

4.4 The FCE and its GSE shall interface with X-43C specific 8-Ft. HTT infrastructure and systems.

4.5 The Contractor shall provide a model support pedestal for the FCE. The model support pedestal shall include all hardware required for its integration with the FCE and the 8-Ft. HTT systems and hardware. The model support pedestal shall include DV forebody and aftbody simulation hardware.

4.6 The FCE shall have provisions for fuel and igniter system purging.

4.7 The FCE shall withstand 8-Ft. HTT simulated Mach 7 flight conditions at a dynamic pressure of 1250 psf and Mach 5 flight conditions at a dynamic pressure of 1750 psf.

4.8 The FCE shall be designed to withstand at least 25 cycles at the Mach 5 test condition plus at least 25 cycles at the Mach 7 test condition in the 8-Ft. HTT test environment with exposure time up to 60-second duration for each cycle.

4.9 The FCE shall be capable of test section pressure changes from atmospheric pressure to approximately 2.0 psia in two seconds and from 2.0 psia to approximately 0.5 psia in an additional seven seconds. The internal cavities shall be vented such that component and material loads do not exceed design limit conditions.

4.10 The FCE shall be capable of withstanding +/- 1g of vertical acceleration during the injection and retraction process and the aerodynamic loads imposed by injection through the tunnel shear layer.